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Experiments in Growing Tomatoes for Canning

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EXPERIMENTS IN GROWING TOMATOES FOR CANNING

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INTRODUCTION

Ohio produces about 6 per cent of the tomatoes grown for processing in the United States. In the list of principal producing states Ohio stands sixth (table 1). In yield per acre, however, Ohio is exceeded only by New York.

In the past decade the production of tomatoes for canning in Ohio has doubled (table 2). During this expansion, the yield has been maintained at an average of about 6 tons per acre.

SOILS USED FOR TOMATOES

Production of tomatoes for processing is largely restricted to western Ohio where the soils are derived from limestone (figure 1). The most concentrated production is in an area extending southwestward from Lake Erie, known as the Old Lake Bed.

The Old Lake Bed is topographically level and has black, fertile soil which is characteristically high in lime and phosphate. Soil samples collected from 50 representative tomato fields in this area showed a pH ranging from 6.3 to 7.8; they averaged 156 pounds of available phosphorus per acre by Truog's test (8). These findings agree with the early analyses of Ames and Gaither (1), who found the soils of western Ohio to be considerably higher in phosphorus than those of eastern Ohio.

As the tomato plant requires a higher level of available phosphorus than most crops (2), the high content of available phosphorus in the soils of northwestern Ohio may largely explain the concentration of acreage depicted in figure 1. It is true that tomatoes thrive elsewhere when adequately fertilized, but in northwestern Ohio they succeed as an incidental farm crop without exceptional applications of fertilizer.

The soils of the Old Lake Bed vary from sands to clays, with clay loams predominating. Tomatoes are grown on soils of all these textures. Since clay loams predominate, the bulk of the crop is grown on heavy soil, mostly underlaid with a tight clay subsoil.

EFFECT OF WEATHER ON YIELD

Weather records for the summer months for 20 years are given in table 3; they are listed in the order of the seasonal average yield of tomatoes grown for processing. In general, the seasons of high yields were warm and dry. As shown more clearly in table 4, the years having June temperature above

[1]Acknowledgments. At the outset of this work the writer was not well acquainted with problems of growing tomatoes for canning and, consequently, sought advice from canning companies, from county agricultural agents, and from the Agricultural Extension Service of The Ohio State University. He is, therefore, much indebted to numerous individuals who generously gave helpful advice. Credit should also be shared with Serge Harmon, Superintendent of the Northwest Test Farm, who was in charge of the field experiment.

TABLE 1.—Tomatoes grown for processing

Average annual production of leading states for the pre-war decade 1931-1940. From Agricultural Statistics, 1943

	Production	Acres	Yield per acre
	Tons	*No.*	*Tons*
California	314,500	55,500	5.68
Indiana	313,200	74,800	4.15
Maryland	181,800	51,100	3.56
New Jersey	161,000	31,700	5.08
New York	123,500	16,600	7.44
Ohio	102,600	16,800	6.11
Virginia	60,200	19,800	3.04
United States	1,631,800	372,800	4.38

TABLE 2.—Annual production of tomatoes for processing in Ohio for the past 20 years

From Agricultural Statistics, 1928 to 1943

	Acres	Production	Yield per acre	Average price per ton
	No.	*Tons*	*Tons*	*Dollars*
1925	8,560	51,400	6.0	13.09
1926	8,000	38,400	4.8	11.20
1927	10,000	45,000	4.5	12.45
1928	10,400	60,300	5.8	11.60
1929	10,950	52,600	4.8	12.00
5-year average	9,580	49,500	5.2	12.07
1930	12,400	67,000	5.4	12.00
1931	10,300	61,800	6.0	9.70
1932	9,300	60,400	6.5	7.60
1933	9,800	70,600	7.2	9.30
1934	12,300	82,400	6.7	9.30
5-year average	10,800	68,400	6.3	9.58
1935	17,000	81,600	4.8	9.70
1936	17,500	131,200	7.5	10.50
1937	19,000	64,600	3.4	13.30
1938	23,700	156,400	6.6	12.10
1939	23,200	178,600	7.7	10.80
5-year average	20,100	122,500	6.0	11.28
1940	23,600	125,100	5.3	10.60
1941	28,500	213,800	7.5	12.80
1942	33,000	217,800	6.6	17.50
1943	22,800	86,600	3.8	22.70
1944	25,000	165,000	6.6	24.40
5-year averege	26,600	161,700	6.0	17.60

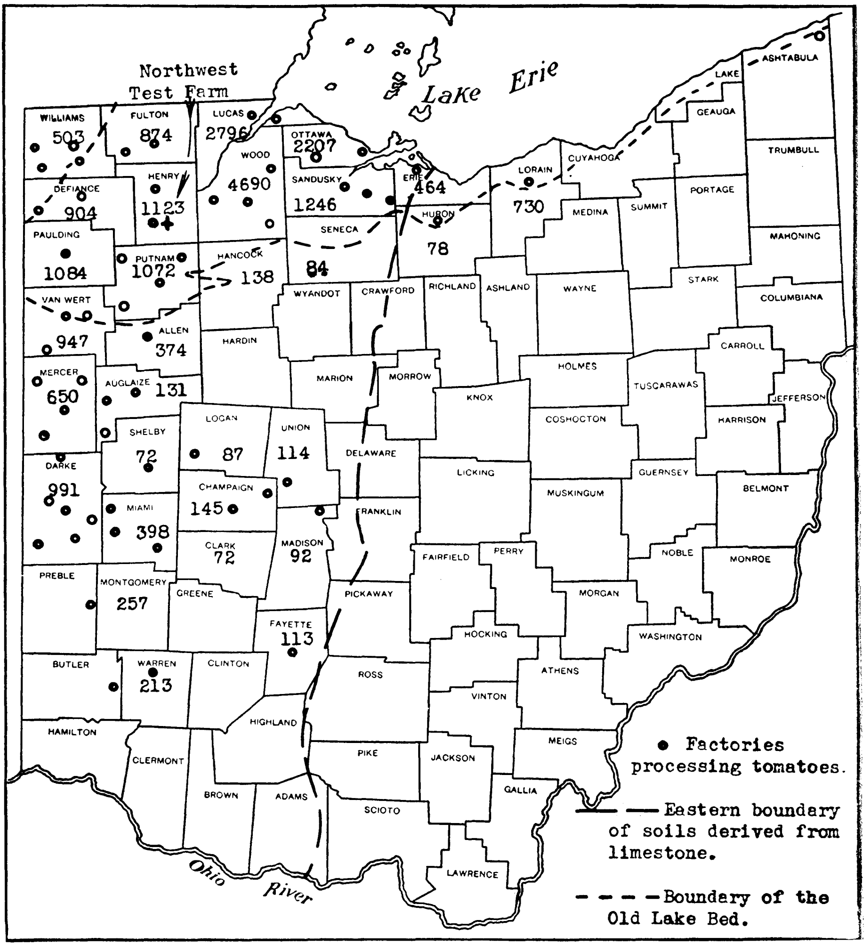

Fig. 1.—Area where tomatoes are grown as a field crop

Acreage in counties with an average of over 1.5 acres per grower and a total of over 70 acres according to 1939 census. Location of factories in or near these counties furnished by Ohio Canners Association. Geological boundaries from Conrey, Classification of Ohio Soils (3).

68° F. and less than 12.5 inches of rainfall during the four summer months were years when tomatoes yielded 6 tons or more per acre. There was one exception, the severe drouth year of 1930. All other drouth years gave yields above average.

TABLE 3.—Relation of weather to annual yield

Toledo weather records* from Climatological Data, U. S. Weather Bureau

Year	State average yield	Rainfall					Mean temperature		
		May	June	July	August	Total 4 months	June	July	August
	Tons	*In.*	*In.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*
1939	7.7	1.43	4.91	2.16	1.08	9.58	72.0	73.5	72.4
1936	7.5	2.00	2.31	3.26	1.62	9.19	68.1	76.0	75.0
1941	7.5	4.42	3.08	1.42	1.79	10.71	70.6	74.5	72.0
1933	7.2	5.88	1.02	2.13	2.99	12.02	75.4	75.0	70.9
1934	6.7	0.69	1.83	1.64	1.80	5.96	74.8	77.4	71.1
1938	6.6	3.03	4.28	2.97	0.86	11.14	68.6	74.6	75.8
1942	6.6	2.51	3.47	3.47	3.81	13.26	69.8	74.5	70.4
1932	6.5	2.01	1.11	3.23	1.43	7.78	70.5	73.8	73.6
1925	6.0	1.84	2.66	3.03	2.05	9.58	72.2	72.1	72.5
1931	6.0	1.17	4.85	1.24	2.82	10.08	70.4	77.8	73.2
1928	5.8	1.44	3.89	3.28	2.68	11.29	63.6	74.2	72.9
1924	5.4	2.03	5.35	2.63	1.66	11.67	66.4	70.6	71.4
1930	5.4	1.05	1.76	0.68	0.86	4.35	70.4	75.4	72.8
1940	5.3	3.73	3.41	3.29	3.60	14.03	70.2	74.2	71.3
1926	4.8	0.70	3.37	0.83	7.64	12.54	65.0	72.8	73.2
1929	4.8	3.62	3.03	3.98	1.30	11.93	66.4	73.6	69.0
1935	4.8	2.75	2.79	1.17	3.85	10.56	66.4	77.6	72.6
1927	4.5	2.60	2.95	2.48	2.20	10.23	64.6	72.5	66.6
1943	3.8	8.04	2.18	6.05	1.99	18.26	73.2	73.2	71.1
1937	3.4	2.23	6.67	4.55	2.78	16.23	68.6	74.0	74.8
Normal	....	3.49	3.33	3.02	2.86	12.70	67.2	71.7	70.2

*No single weather station gives a true picture of the rainfall throughout the tomato district. The Toledo records were selected for this table because the most intensive production lies within a radius of 25 miles of Toledo.

TABLE 4.—Relation of weather to annual yield

Same data as in table 3

Seasons with June mean temperature above 68 °F. and with less than 12.5 inches of rainfall from May through August				Seasons with June mean temperatures below 68 °F. or with over 12.5 inches of rainfall from May through August			
Year	June mean temperature	Rainfall, May through August	State average yield of tomatoes	Year	June mean temperature	Rainfall, May through August	State average yield of tomatoes
	°*F.*	*In.*	*Tons*		°*F.*	*In.*	*Tons*
1939	72.0	9.58	7.7	1942	69.8	13.26	6.6
1936	68.1	9.19	7.5	1928	63.6	11.29	5.8
1941	70.6	10.71	7.5	1924	66.4	11.67	5.4
1933	75.4	12.02	7.2	1940	70.2	14.03	5.3
1934	74.8	5.96	6.7	1926	65.0	12.54	4.8
1938	68.6	11.14	6.6	1929	66.4	11.93	4.8
1932	70.5	7.78	6.5	1935	66.4	10.56	4.8
1925	72.2	9.58	6.0	1927	64.6	10.23	4.5
1931	70.4	10.08	6.0	1943	73.2	18.26	3.8
1930	70.4	4.35	5.4	1937	68.6	16.23	3.4
Average	....	....	6.7	Average	....	....	4.9

At the other extreme, the seasons with excessive rainfall, or with cold weather in June, resulted in poor crops.

In other words, these correlations show that the varieties now being grown and the cultural conditions now being followed are better adapted to hot, dry seasons than to cold, wet years. Consequently, a problem needing to be solved is how to obtain better crops of tomatoes in cold, wet seasons.

CURRENT PRACTICES AND SOME OF THE DIFFICULTIES IN GROWING TOMATOES

Although some growers produce tomatoes as their principal crop, the bulk of the crop is grown by farmers to whom tomatoes are an incidental cash crop. The average planting, according to the 1939 census, in Wood and Paulding counties was 7.9 acres, but in other counties it was 5 acres or less.

Most growers do not attempt to grow their own plants, except where seed is planted directly in the field. Planting seed directly in the field has been widely tried, and some growers, particularly those located on heavy clay soils, prefer this method. The bulk of the acreage, however, is set with southern-grown plants. Prior to the establishment of inspection and certification by southern states, plants were mostly grown under glass in Ohio establishments. These concerns continue to supply plants, but southern plants are now cheaper in price and in recent years have generally proved satisfactory (10). The plants needed for the expanding acreage shown by table 2 have been largely obtained from southern states.

Dependence upon southern plants leads to difficulty when shipments arrive during wet weather. Car lots of plants are received by the canners and then distributed to their growers, but neither canners or growers are equipped to store plants. If they are held for a week or longer, the plants start to rot. It is then very difficult to sort out the good ones, and the stand of plants in the field is often poor.

When conditions are favorable for setting plants upon arrival, excellent stands are almost invaribaly obtained. In the writer's observations, loss from cutworms is infrequent. Flea beetles, a serious pest of tomatoes in eastern Ohio, do some damage to direct seedings in northwestern counties, but they are not numerous on transplants.

During the growing season there are two principal causes of poor crops. One is loss from diseases of foliage and fruit, particularly Septoria leaf spot, early blight, and anthracnose. These diseases prevail throughout Ohio on all types of soil used for tomatoes. As a rule, however, they become serious only in seasons with rainy periods sometime during July, August, or early September. The comparative absence of these diseases in dry seasons accounts in part for the above-average yields in such seasons (table 4).

The second principal cause of poor crops is water-logging of the soil by prolonged rains. Much of the soil of the Old Lake Bed has a tight clay subsoil, and most of the fields are extremely level. During and after heavy rains the soils may be water-logged for several days. Tomatoes appear to survive about as well as any of the cultivated crops, but at times they are stunted or even completely killed. This condition occurred in 1943, with 6 inches of rain in July. The crop estimate for 1943 showed an average yield of only 3.8 tons per acre, but it may also be noted from table 2 that only 22,800 acres appeared in the crop reports; whereas, 33,000 acres were reported in 1942 and 25,000 in 1944. Probably 10 per cent of the 1943 acreage was drowned out and abandoned.

AIM OF THE EXPERIMENTS

The experiments reported here were started in 1941 at the request of the Ohio Canners Association. At the outset, the Association did not suggest specific problems but maintained that with the expansion of the processing industry more information was needed on the specific requirements of the crops.

Field experiments were then undertaken with tomatoes, the leading canning crop in Ohio. Emphasis was placed upon soil and cultural treatments with the aim of determining the procedures which would insure good yields and good quality tomatoes.

These experiments are not completed, but some tentative conclusions can be drawn, and the wide interest in the work justifies this bulletin at this time.

CONDITIONS OF THE EXPERIMENTS

The experiments were conducted at the Northwest Test Farm, located near Holgate in Henry County. As is shown in figure 1, this Farm is centrally located in the tomato-producing area.

The soil is Brookston clay loam, a prominent type of soil in western Ohio and a type widely used for tomatoes. The subsoil is gray or mottled gray clay. The entire farm is well tiled, but the tight clay subsoil precludes rapid drainage. The fields used for these experiments were in alfalfa for 2 years or more prior to plowing for tomatoes.

Methods.—Rutgers, the most popular canning variety of tomato, was used throughout, except where noted. For fertilizer, 0-12-12 at the rate of 400 pounds per acre was drilled just prior to setting the plants. A "starter solution" of one pound of superphosphate per 30 gallons of water was applied at the rate of one-half pint per plant.

Plants were set by hand, 4 feet apart, in rows 56 feet long, except as noted. The dates of setting and the period of harvesting Rutgers were as follows:

DATE	PLANTS SET	CROP HARVESTED
1941	May 23	August 4 to October 2
1942	May 26 and 27	August 12 to October 3
1943	June 4 to 8	August 23 to October 12
1944	May 20 to 24	August 11 to October 3

Harvesting was mostly done by boys of high school age who counted, graded, and weighed the fruits from each row as soon as they were picked. The grading aimed at federal standards, but emphasis was placed upon maintaining a uniform standard throughout each picking. When doubts arose about the grading standards, the federal inspectors, who were located at Holgate and were always cordially helpful, were consulted.

Foliage diseases were well controlled by spraying four times with a copper fungicide.

RESULTS OF THE EXPERIMENTS

SOIL STRUCTURE

In its virgin state, the soil of western Ohio has excellent, granular, porous structure. After years of cropping, the soil becomes sticky, cloddy, and more compact. In this, as in other respects, the soil at the Northwest Test Farm is representative of the general average of the heavily-cropped farms of the district. The deteriorated structure of the soil reduces crop yields most noticeably in wet seasons.

Experiments with crop rotations, and with additions of crop residues to the soil, were started in 1942, with no expectation of appreciably improving the soil in the brief period of 3 years. More immediate results were sought by heavy manuring.

Effect of manure.—Beginning in the fall of 1941, manure from a steer feeding-shed was applied at three rates, the heaviest being 20 tons per acre. Tomatoes were grown in 1942, then the plots were again manured at the same rates, and a second crop was grown in 1943. The experiment was duplicated, beginning a year later; manure was then first applied in the fall of 1942.

As shown in table 5, the applications of 5 tons of manure resulted in practically the same yield as when applied at the rate of 20 tons per acre. Moreover, the 20-ton applications produced increases in yield of only a ton or less per acre (table 6). The increases were of the same magnitude in the dry year of 1944 as in the very wet year of 1943.

TABLE 5.—Effect of rate of manuring on yield and grade

Average yield per acre of duplicate 0.04-acre plots

Manure per acre	Manured 1941 Crop of 1942			Manured 1942 Crop of 1943		
	Grade 1	Grade 2	Culls	Grade 1	Grade 2	Culls
Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
None	6.06	4.65	5.86	3.07	0.76	0.18
5	6.86	7.22	6.08	3.96	0.77	0.26
10	7.16	6.18	7.14	4.55	0.81	0.25
20	6.90	4.61	6.24	4.06	0.79	0.16
	Manured 1941 and 1942 Crop of 1943			Manured 1942 and 1943 Crop of 1944		
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
None	3.09	0.82	0.11	12.17	0.75	0.76
5	3,93	0.80	0.14	12.08	0.80	0.82
10	3.66	0.62	0.21	12.72	0.70	0.84
20	3 49	0.79	0.21	13.18	0.71	0.88

TABLE 6.—Summary of effect of 20 tons of manure per acre

Yield of salable tomatoes*

	With no manure	With 20 tons of manure per acre	Increase due to manure	Time manure was applied
	Tons per acre	*Tons per acre*	*Tons per acre*	
1942	10.71	11.51	0.80	Fall of 1941
1943	3.91	4.28	0.37	Fall of 1941 and 1942
1943	3.83	4.85	1.02	Fall of 1942
1944	12.92	13.89	0.97	Fall of 1942 and 1943

*"Salable" tomatoes include Grades 1 and 2.

As a whole, the increases were about the same as those produced by additional fertilizer, and they might well be attributed to the fertility supplied by the manure. The present deduction, then, is that liberal applications of manure for one or two seasons did not have sufficient effect on the structure of the soil to be definitely reflected in increased yields of tomatoes.

The restoration of soil structure to the point where better yields can be obtained in wet seasons is presumably a long, slow process.

Time of plowing.—For three seasons part of the experimental blocks were plowed in the fall, and the others were plowed just prior to setting plants in the spring. The fall-plowed soil, exposed during the winter, became granular in the top inch and was easily fitted for setting plants. The spring-plowed soil was cloddier and more difficult to prepare.

In all three seasons the average yield of tomatoes on the fall-plowed blocks exceeded the yield on the spring-plowed ones. The difference was conspicuous, however, only in 1944 when dry weather ensued after setting (table 7). With a difference of over 4 tons in 1944, the average increase for the three seasons became 2 tons per acre.

TABLE 7.—Comparison of effect of fall plowing and spring plowing on yield of salable tomatoes

	Tons per acre	
	Fall-plowed	Spring-plowed
1942	11.88	11.30
1943	4.98	4.37
1944	12.92	8.18
Average	9.93	7.95

Presumably the granulation of the exposed soil during the winter is a transient, rather than a lasting, improvement in structure. On cloddy soils, however, it supplies a small amount of granular soil to pack around the plants when they are set.

Ridging.—Plowing the soil into ridges in the fall might be expected to be beneficial because more soil is exposed to the action of winter weather. Moreover, if the plants were set on the ridges in the spring, they might be up out of standing water during prolonged rains.

Ridging was tested in 1942. The ridges were about 5 feet apart and about 10 inches higher than the intervening ditches. There were six ridges in a plot and then an equal plot of level soil; these were replicated four times. Plants were set on the ridges and at the same spacing on the level checks. No difference was observed in their growth. After a 3-inch rain in August, water stood in the ditches between the ridges for 2 days. At this date, the plants filled the rows so that many of the fruits lay in the standing water in the ditches. Such fruits were so dirty that they had to be laboriously wiped to classify them as to grade. The final crop was in no way benefited by the ridging. The yield of usable tomatoes from the ridged plots averaged 11.9 tons per acre, that from the level check plots 12.4 tons. Moreover, with the implements at hand, leveling down the ridges for the following planting of oats and alfalfa was a slow task. From this one test, ridging appeared to be entirely impractical for growing tomatoes on a field scale, and the experiment was discontinued.

FERTILIZERS

As mentioned in the introduction, the soils used for tomatoes have a relatively high content of available mineral nutrients. The soil of the experimental fields tested practically the same as the average of the samples collected from 50 growers' fields. The pH was 6.3. The available phosphorus was 126 to 158 pounds per 2 million pounds of soil by Truog's test (8). Replaceable potassium was 200 to 250 pounds by Thornton's test (6).[2]

On soil showing such tests, relatively small applications of fertilizer might be expected to suffice. The tomato plant, however, in spite of its large root system, is not as efficient in obtaining its nutrients from the soil as are some other crops. For example, in a long continued experiment at the Washington County Experiment Farm, where tomatoes are grown in rotation with sweet corn and other vegetables, it was found that tomatoes require nearly twice as much phosphate and potash as does sweet corn (2). Correspondingly, the amount of fertilizer recommended for tomatoes is somewhat more than that recommended for corn.

The application of 400 pounds per acre of 0-12-12, which was adopted as a standard in these experiments, has appeared to be sufficient. The only time any symptoms of mineral deficiency were detected, either in the appearance of the plants or by chemical tests of the tissues, was late in 1942 on plants that had produced over 15 pounds of ripe fruit.

Correspondingly, a 4-year test of double the regular amount of phosphate gave no significant increase in yield (table 8). This test was conducted because large applications of phosphate are commonly needed by tomatoes in eastern Ohio, but evidently moderate applications are ample on the tomato soils of western Ohio.

TABLE 8.—Effect of double amount of phosphate in fertilizer on yield and grade

Fertilizer drilled prior to setting plants. Average yield of duplicate single rows, in tons per acre

Year	Standard fertilizer, 0-12-12			Double phosphate, 0-24-12			Increase
	Grade 1	Grade 2	Total salable	Grade 1	Grade 2	Total salable	Total salable
1941	8.18	2.14	10.32	7.56	2.63	10.19	—0.13
1942	7.66	6.55	14.21	8.26	6.64	14.90	0.69
1943	4.16	1.23	5.39	4.52	1.08	5.60	0.21
1944	7.37	0.41	7.78	7.13	0.53	7.66	—0.12
Average	6.84	2.58	9.42	6.87	2.72	9.59	0.17

Plowing down nitrogen fertilizer.[3]—In the two dry seasons of 1941 and 1944, symptoms of nitrogen deficiency were not observed, but in the wetter years of 1942 and 1943 the deficiency was conspicuous toward the end of the season. Plowing down nitrogen fertilizer in the form of cyanamid was tested three seasons and resulted in an average increase in yield of over 2 tons per acre (table 9).

In 1942 a comparison was made of the effect of applying cyanamid in the furrow and broadcast prior to plowing. The broadcast application gave a slightly higher yield and was used in the tests of the following seasons.

The procedure of applying nitrogen fertilizer, either broadcast before plowing or in the furrow, is peculiarly suited to tomatoes. Tomatoes should not have too much available nitrogen at the outset, because the plants may become too vegetative and fail to set fruit on the early clusters. But after fruits set the nitrogen requirement mounts.

[2]Tests made by I. W. Wander, Assistant Horticulturist, Ohio Agricultural Experiment Station.

[3]Conducted with financial aid from the American Cyanamid Co.

TABLE 9.—Effect of nitrogen fertilizer on yield and grade

Cyanamid broadcast just before spring plowing. Average yield of triplicate 0.01-acre plots, in tons per acre

Year	Check: no nitrogen fertilizer			Cyanamid: 200 pounds per acre			Increase
	Grade 1	Grade 2	Total salable	Grade 1	Grade 2	Total salable	Total salable
1942	5.21	5.44	10.65	8.04	6.67	14.71	4.06
1942*	5.21	5.44	10.65	7.13	6.79	13.92	3.27
1943	2.61	1.04	3.65	4.16	1.23	5.39	1.74
1944	5.53	0.51	6.04	6.28	0.42	6.70	0.66
Average	4.45	2.33	6.78	6.17	2.77	8.94	2.16

*Cyanamid applied in furrow instead of broadcast prior to plowing. Data not included in the average.

Whether the same response to nitrogen fertilizer would be obtained on other soils depends largely on their structure. More granular, porous soil would be expected to develop more nitrates by the natural processes of nitrification, and, correspondingly, they would need less nitrogen fertilizer. Even in the wet season of 1943, some soils in the district produced better crops without nitrogen fertilizer than were obtained at the Test Farm with it. Most tomato soils, however, are not superior to that used for these experiments. Consequently, even though yields were not appreciably increased in dry seasons, the benefits from plowing down nitrogen fertilizer in wet seasons were so conspicuous that the practice may be widely advocated.

Incidentally, nitrogen fertilizer proved more effective than manure in supplying the crops' nitrogen requirement. In the wet season the manure evidently did not nitrify rapidly enough.

Starter solutions.—Fertilizer added to the water applied at the time of setting plants in the field is called "starter solution". Fertilizer thus applied gave small but consistent increases in growth and yield in every season (table 10). Although an increase averaging only 0.7 tons per acre might seem practically insignificant, this resulted from only 10 pounds of high-analysis fertilizer, costing less than a dollar, and with no extra labor except weighing it out in small lots to be poured into the transplanting water.

TABLE 10.—Effect of starter solutions on yield of salable tomatoes

Applications equivalent to 4.5 pounds of the fertilizer formula per 1000 plants, applied in 100 gallons of water.* Yield in tons per acre

	No fertilizer. Water only	Complete mixture. Nitrogen, phosphate, and potash	Nitrogen and phosphate. No potash	Nitrogen and potash. No phosphate	Phosphate and potash. No nitrogen
Fertilizer formula ☞	....	20-46-24	20-46-0	20-0-24	0-46-24
1941	8.33	9.77	9.09	8.66	9.27
1942	12.74	12.99	13.10	13.33	12.61
1943	5.88	6.38	6.30	5.48	5.74
1944	12.67	13.34	13.02	12.88	12.90
Average	9.91	10.62	10.38	10.09	10.13

*The amount of water applied was 0.1 gallon per plant, which is nearly double the usual application. This rate was adopted because the soil was dry during the first year of the experiment. Judging from experiments in eastern states (4, 5, 7), starter mixtures can be safely applied at the rate of 3 to 4 pounds of fertilizer in 50 gallons.

The data of table 9 also indicate that the increase in yield was due more to the nitrogen and phosphate than to the potash in the fertilizer mixtures.

At the time this experiment was started, soluble fertilizers for starter solutions were not commonly listed by Ohio dealers. The experimental mixtures were compounded from technical grade chemicals. Similar commercial mixtures are, however, now obtainable through fertilizer dealers.

VARIETIES

Rutgers and Indiana Baltimore are the two prominent varieties grown for canning in Ohio. In a comparative test of the two varieties (table 11), they yielded approximately the same in the dry seasons of 1941 and 1944, but Indiana Baltimore gave the higher yield in the wetter years of 1942 and 1943.

TABLE 11.—Comparative yields of Rutgers and Indiana Baltimore varieties

Yield in tons per acre

Year	Rutgers			Indiana Baltimore		
	Grade 1	Grade 2	Total salable	Grade 1	Grade 2	Total salable
1941	9.44	0.99	10.43	7.69	2.01	9.70
1942	4.99	7.70	12.69	5.67	10.36	16.03
1943	4.26	1.21	5.47	6.52	1.10	7.62
1944	12.69	0.59	13.28	12.74	0.87	13.61
Average	7.85	2.62	10.47	8.16	3.58	11.74

Indiana Baltimore is an earlier variety than Rutgers; its largest pickings are about a week earlier. The difference is illustrated by the picking records of 1942 (table 12). By September 2, Indiana Baltimore had produced 10 tons per acre, as compared with only 4 tons from Rutgers. The earliness of Indiana Baltimore accounts for the fact that it outyielded Rutgers in the cold, wet season of 1943. The plants of the two varieties were approximately the same size, they were equally loaded with green fruits, but Indiana Baltimore produced one good picking before frost while Rutgers did not. Consequently for the season as a whole, Indiana Baltimore outyielded Rutgers by nearly 50 per cent.

TABLE 12.—Comparative earliness and average weight of individual tomatoes of four varieties

Data of the favorable season of 1942

Variety	Yield of salable tomatoes per acre			Percentage picked before September 2	Average weight of individual tomatoes
	Picked before September 2	Picked after September 2	Total for season		
	Tons	*Tons*	*Tons*	*Pct.*	*Lb.*
Cobourg	6.65	1.61	8.26	80.5	0.306
Marglobe	5.52	4.84	10.36	53.3	0.372
Indiana Baltimore	10.12	5.91	16.03	63.1	0.389
Rutgers	4.04	8.65	12.69	31.8	0.410

Varieties of the Bonny Best type, such as Nysate, Cobourg, and John Baer, ripen earlier than Indiana Baltimore (Cobourg is listed in table 12) and are standard canning varieties in New York. Because of the low yield of Cobourg in 1942, no variety of this type was tested here in 1943, but the weather in 1943 was so cool that early varieties might have given the best crops.

In all respects except earliness, Rutgers stands out as the best canning tomato in Ohio; its acreage probably exceeds all other varieties combined. In most seasons it produces a higher proportion of grade-1 fruits than does Indiana Baltimore (table 11) and the fruits are slightly larger in size (table 12). When ripened under the shade of leaves, the fruits of Rutgers are a handsome red, both outside and inside. Only rarely do the fruits develop blossom-end rot, even in times of severe drouth. Their only characteristic defect is deep, radial cracking, and, unless these cracks become infected with mold, this defect does not lower the grade of tomatoes to be processed into a strained product.

SPACING OF PLANTS

In most of these experiments the plants were set 4 feet by 4 feet. In 1941 and 1942 the plants at this spacing seemed to be too close together, since the border plants, with roots extending 7 feet into the fallow roadways, yielded almost 50 per cent more salable tomatoes than did the interior plants.

Tests of wider spacing were made in the following seasons. In these seasons, however, the plants never attained normal size; they were stunted by the cold, wet weather of 1943, and in 1944 the test was on spring-plowed soil that did not retain enough moisture to start the plants properly. Wider spacing resulted in slightly higher yields per plant, but on an acre basis the 4 by 4 planting was best (table 13).

TABLE 13.—Effect of planting distances on yield of salable tomatoes

	Pounds per plant*			Tons per acre		
Planting distance☞	4′ by 4′	4′ by 5′	4′ by 6′	4′ by 4′	4′ by 5′	4′ by 6′
1943	4.59	4.93	5.98	6.25	5.37	5.43
1944	5.62	6.29	6.51	7.65	6.45	5.91

*The number of plants per acre at these spacings is as follows:
At 4′ by 4′ : 2722
At 4′ by 5′ : 2178
At 4′ by 6′ : 1815

More data are needed before definite recommendations can be made as to the most profitable spacing over a period of years. The observations of 1942, however, merit further consideration. This was a season in which the plants made large growth and gave 20-ton yields. However, as the fruit developed the leaves began dying off. The dying of leaves was not due to disease; the symptoms were those of nitrogen deficiency. By the time of the large pickings in September, the loss of leaves left many of the fruits exposed to direct sunlight. The exposed fruits failed to color properly or became sun scalded, with the result that there was a high proportion of grade 2 and cull fruits. The high proportion of grade 2 fruits is shown by the data of table 11, and in addition there were about 5 tons of culls per acre.

These observations suggest that to insure a crop of high quality on large plants, nitrogen fertility must be especially supplied or the plants must be spaced wider than 4 feet by 4 feet.

SPRAYING FOR DISEASE CONTROL

Tests of new types of fungicides for control of diseases on the foliage and fruits of tomatoes are being conducted at several localities by J. D. Wilson, of the Department of Botany and Plant Pathology (11). At the Northwest Test Farm this work was limited to a test of a "fixed-copper" compound applied as a spray.

TABLE 14.—Effect of copper spray on yield and grade

Yield in tons per acre of Indiana Baltimore sprayed four times with 4 pounds of Dupont "Copper A", 4 pounds of flour, and one-third quart of Turgitol in 100 gallons of water

Year	Unsprayed			Sprayed			Increase due to sprays		
	Grade 1	Grade 2	Culls	Grade 1	Grade 2	Culls	Grade 1	Grade 2	Total salable
1942	2.53	3.82	2.77	5.67	10.36	6.68	3.14	6.54	9.68
1943	2.66	0.64	0.65	6.52	1.10	0.12	3.86	0.46	4.32
1944	12.53	0.93	1.27	12.95	0.92	0.77	0.42	—0.01	0.41
Average increase	....	....	....	....	....	....	2.47	2.33	4.80

Excellent control of diseases was obtained. Foliage diseases were most serious in 1942, a season otherwise very favorable for tomatoes. Spraying increased the yield of Indiana Baltimore nearly 10 tons per acre. On the other hand, in the relatively dry season of 1944, diseases were negligible and the effect of spraying was insignificant (table 14). The 3-year average increase of 4.8 tons per acre is perhaps somewhat larger than might be expected over a longer period of years. Wilson (9) estimated the increase to be expected in Ohio in seasons when diseases are prevalent as about 3 tons per acre.

OBSERVATIONS ON GROWTH OF PLANTS

The roots of tomatoes tend to grow laterally rather than downward. As long as the soil has ample moisture, the main roots are found to be only a few inches deep; they can be largely exposed by sweeping away the loose surface soil. In the moist year of 1942, roots were found extending 7 feet into the roadways surrounding the experimental plots. On the other hand, when drouths occur, as in 1941 and 1944, the roots turn downward (figure 2). Where large cracks developed in the soil, the roots were found adhering to the walls of these cracks to a depth of 30 inches.

If plants start to grow rapidly soon after they are set, a number of large basal branches appear. These branches flower and fruit a week or two later than the main stem. To a considerable degree, the potential production of a plant depends upon the number of basal branches. In these experiments, thrifty plants averaged seven large basal branches in 1941 and eight in 1942.

Secondary branches develop just below the fruiting nodes on both the main stem and the basal branches. These, however, are relatively insignificant, because their fruits develop much later.

Fig. 2.—In the dry season of 1941 main roots extended laterally about 2 feet and then turned downward. Photographed July 24

On typical, thrifty plants of Rutgers producing 11 pounds of ripe fruit, the clusters that bore this fruit were located as follows:

On the main stem: 4 clusters
On eight basal branches: 13 clusters
On three secondary branches: 4 clusters

Another characteristic of tomato plants which affects production is the failure of the early clusters to set fruit if the plants are making rapid vegetative growth. It is associated with an excess of available nitrates in the soil. This failure to set fruit was not found in the experiments reported here, but it has been observed in some fields on sandier soils.

DISCUSSION AND PRACTICAL CONCLUSIONS

Potential production in Ohio.—Viewed as a whole, these experiments may be taken simply as a demonstration that, with proper cultural conditions, crops of tomatoes averaging 10 tons per acre may be grown on average soil in northwestern Ohio. This is not in any sense a phenomenal yield, but it is sufficiently above the general average of the United States to substantiate the assertion that the soil and climate of northwestern Ohio are distinctly favorable for tomatoes as a field crop.

Although the Ohio acreage has been increasing, the potential production is far beyond that of the present. In Wood County, the leading tomato county of the State, only 1.74 per cent of the cropped land was in tomatoes in 1939. This county had only 4,690 acres of tomatoes as compared with 96,130 acres of corn. Soil suitable for corn throughout northwestern Ohio is generally suitable for tomatoes. Hence, the continued expansion of tomato production is not restricted by the available soil, but it depends rather upon the volume that can be handled by the processors, upon the relative profit to the farmer from tomatoes as compared with the profit from corn, upon the supply of labor for picking, and upon related economic factors.

Selection of varieties.—Rutgers is an ideal canning variety for Ohio in all respects except earliness. The higher yield from Indiana Baltimore, obtained in these experiments, can be attributed to its ripening its crop a few days earlier than Rutgers. As a practical procedure, then, to insure better yields in cool seasons and at the same time to even out the daily pickings, it would seem advisable to supplement Rutgers with part of the acreage in Indiana Baltimore and, perhaps, part in some still earlier variety, such as Bonny Best or Cobourg.

Distance of planting.—Farmers who grow a few acres of tomatoes as an incidental crop commonly set the plants in rows 42 inches apart. They realize that this is somewhat too close, but they do it because their cultivators are set to work corn in rows 42 inches apart and the cultivators are not readily adjustable to wider rows.

The close spacing not only makes harvesting difficult, because the pickers stumble and tramp on the vines, but the competition between plants for moisture and nutrients causes premature dying of the leaves. By early September the dying of leaves frequently leaves much of the fruit exposed to damage by direct sunlight.

The opinion widely prevails that this defoliation is solely due to diseases and could be prevented by protecting the foliage with fungicide. It is true that diseases appear in most seasons and that they may be more prevalent in close plantings than in wider rows, but, in the dry season of 1944 when diseases were negligible, many fields with rows 42 inches apart were observed with leaves dying off prematurely.

Fertilizer applications.—The experiments show that three distinct applications of fertilizer are needed for tomatoes on Brookston clay loam. The first is nitrogen fertilizer, such as cyanamid or sulfate of ammonia, plowed down or applied in the furrow, at the rate of about 200 pounds per acre. The second is ordinary mixed fertilizer, such as 0-12-12 at about 400 pounds per acre, applied with the planter or drilled just prior to setting the plants. And third is a special, soluble, "starter" mixture, which will supply at least nitrogen and phosphate, dissolved in the water applied when setting the plants.

These specific recommendations apply only to the fertilie, heavy soils of the Old Lake Bed area. If tomatoes are to be grown on less fertile soil, the one fact to keep in mind is that the tomato plant is a relatively weak forager for mineral nutrients and consequently needs more fertilizer than does corn.

Controlling foliage diseases.—Comparatively few tomato fields in Ohio are sprayed or dusted for control of foliage diseases. In spite of frequent outbreaks of diseases, the 10-year average yield for the State has been 6 tons per acre. In the most recent season of severe disease, 1942, the average was 6.6 tons.

Wilson, studying these diseases, has observed that the infections characteristically do not develop seriously until the fruits start to ripen (11). The plants appear to have some resistance that declines with fruiting. Consequently, at least half the crop ripens before the leaves are killed to the point where growth ceases and the exposed fruits are seriously damaged by exposure to the sunlight. Thus, if other conditions are favorable, yields of 6 tons or more are harvested.

For the grower who is satisfied with 6-ton yields, controlling foliage diseases is not essential. For the grower who plants in rows 42 inches apart, it might be questionable whether the application of fungicides would prove profitable. On the other hand, for the grower whose tomatoes are a principal crop and whose tomatoes are properly spaced, the application of fungicides would seem to be a highly profitable operation. The cost per acre, according to Wilson (9), is about $3 per application. As four or five applications suffice, the total cost would be only $12 to $15 per acre to give an anticipated increase of about 3 tons per acre. Moreover, from the processors' viewpoint, if growers would control foliage diseases the processors would be assured of a good volume of high-quality tomatoes until the close of the season.

SUMMARY

The climate and soil of northwestern Ohio are favorable for tomatoes as a field crop. The 10-year average yield of tomatoes grown for processing in Ohio is over 6 tons per acre—almost 2 tons above the national average.

During the past 20 years, there were ten seasons with average yields of 6 tons per acre or more. Of these ten seasons, nine had mean June temperatures *above* normal and nine had summer rainfall *below* normal. In general, then, warm, dry seasons are most favorable for tomatoes.

The district of most concentrated acreage is known as the Old Lake Bed. The soil is of limestone origin, nearly neutral in reaction, and relatively high in available phosphorus.

Field experiments have been conducted for four seasons on Brookston clay loam at the Northwest Test Farm, centrally located in the tomato district. All of the problems of growing the crop are not considered to be solved, but the results of practical application are as follows:

1. Indiana Baltimore variety ripened fruits about a week earlier than Rutgers and averaged 11.7 tons of salable tomatoes per acre compared with 10.5 tons from Rutgers. On the other hand, in size and grade, Rutgers was slightly superior. Both varieties are recommended.

2. Fall plowing proved better than spring plowing.

3. Nitrogen fertilizer (cyanamid) plowed down gave increases in yield averaging 2 tons per acre.

4. Fertilizer in the water applied at transplanting gave small but consistent increases in yield.

5. Spraying with a copper fungicide effectively controlled foliage diseases.

6. The combination of fall plowing, adequate fertilizer, and the application of a fungicide gave yields averaging over 10 tons per acre, about 4 tons above the State average.

In the rainy season of 1943, however, the best treatments gave yields of only 6 tons per acre. The important problem of obtaining really good crops of tomatoes in wet seasons presumably involves an improvement of the soil structure, and this has not been attained in the brief period of these experiments.

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